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Average Lifetime Periods for Light-Duty Trucks and Heavy-Duty Vehicles

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Technical Report

Average Lifetime Periods for Light-Duty Trucks and Heavy-Duty Vehicles

by

Glenn W. Passavant

November 1979

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The Clean Air Act Amendments of 1977 mandate the U.S. Environmental Protection Agency to further control emissions from light-duty trucks and heavy-duty engines. This technical report uses published vehicle scrappage and mileage accumulation data to estimate average lifetime periods for light-duty trucks and heavy-duty engines. These lifetime periods can be used in the air quality, economic impact, and cost effectiveness analyses associated with the pending and upcoming rule-making actions affecting light-duty and heavy-duty engines.

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Table of Contents

		page
I	Foreword	1
II	Summary	1
III	Background	2
IV	Determination of the Average Lifetime Periods	2
	a. Methodology	2
	b. Scrappage Rates	3
	c. Average Mileage Accumulation Rates	3
	d. Calculations	11
	e. Discussion and Conclusions	20

I. Foreword

An accurate estimate of the average lifetime period for any emissions source is an essential factor in determining the lifetime operating costs and emissions reductions which can be expected in any emission control strategy.

The Clean Air Act Amendments of 1977 mandate the U.S. Environmental Protection Agency to further control emissions from light-duty trucks and heavy-duty engines.

This technical report uses published vehicle scrappage and mileage accumulation data to estimate average lifetime periods for light-duty trucks and heavy-duty engines. These lifetime periods can be used in the air quality, economic impact, and cost effectiveness analyses associated with the pending and upcoming rulemaking actions affecting light-duty trucks and heavy-duty engines.

II. Summary

This technical report estimates average lifetime periods for light-duty trucks and heavy-duty vehicles.

The average lifetime in miles and years for any vehicle in either of these two classes was estimated using scrappage rate data and mileage accumulation data. These data were then used in a simple statistical procedure to estimate average lifetime periods at:

Light-duty trucks (≤ 6,000 lbs. GVWR)	122,000 miles/12 years
Light-duty trucks (6-8,500 lbs. GVWR)	119,000 miles/12 years
Composite LDT class (0-8,500 lbs. GVWR)	120,000 miles/12 years
Heavy-duty gasoline-fueled vehicles (>8,500 lbs. GVWR)	114,000 miles/8 years
Heavy-duty diesel vehicles (>8,500 lbs. GVWR)	475,000 miles/9 years

These lifetime periods can be used in the regulatory analyses associated with the upcoming light-duty trucks and heavy-duty vehicle/engine rulemaking actions.

III. Background:

The EPA is now involved in the preparation/promulgation of several rulemaking packages involving light-duty trucks and heavy-duty engines. The average lifetime periods of these vehicles/engines (hereafter referred to as vehicles only) in both miles and years is an essential input in determining the environmental impact, cost, and cost effectiveness of these rulemaking packages. The average lifetime in miles is used to compute the emissions decrease per vehicle and is also necessary to determine changes in operating costs which are a function of mileage. The average lifetime in years is used to compute operating costs which are functions of time. The cost effectiveness is then computed from these cost and benefit figures.

The average lifetime period as defined in this report is the length of time and/or number of miles an average vehicle is in use. Using the term average implies that some vehicles will have lifetime periods less than the "average" and some will have lifetime periods greater. However, the average lifetime is an effective means of representing the usage pattern for a large fleet of light-duty trucks or heavy-duty vehicles.

IV. Determination of the Average Lifetime Periods

A. Methodology

The average lifetime miles of a fleet of vehicles produced in the same year can be expressed by the formula:

$$ALM = \sum_{i=1}^{n} f_i m_i$$

where:

ALM = average lifetime miles

i = vehicle/engine age.

n = age at which last vehicle/engine of a fleet is scrapped.

f_i = fraction of vehicles/engines which are scrapped at age i.

m_i = average cumulative mileage on vehicles which are scrapped at age i.

Therefore, if the scrappage and average mileage accumulation rates for a fleet of vehicles are known, the average lifetime mileage and period can be determined.

B. Scrappage Rates

The scrappage rates used in this report were taken from a report prepared by Michigan Technological University under contract to EPA.1/2/ The scrappage rates were computed by contrasting known factory sales, as they appear in MVMA publications, with corresponding model year stock of vehicles estimated from the 1972 Census of Transportation. For example, to compute the cumulative scrappage rate at 9 years for vehicles produced in 1970 the method would simply be:

$$\frac{\text{Total 1970 sales - 1979 registrations of 1970 vehicles}}{\text{Total 1970 sales}}$$

This methodology can then be applied to different classes of vehicles for different years and the cumulative scrappage rates can be computed.

To overcome some data acquisition and application problems cumulative scrappage rates were computed for only three major categories: (Light-Duty Trucks: Gas and Diesel) (0-10,000 lb GVWR), HD Gasoline (HDG) (>10,000 lb GVWR) and HD Diesel (HDD) (>10,000 lb GVWR). These cumulative scrappage rates are shown in Table 1 and Figure 1. The annual scrappage rates also shown in Table 1 were computed by subtracting the cumulative scrappage rates.

C. Average Mileage Accumulation Rates

After examining several mileage accumulation rates models the data presented in the current mobile source emission factors document was selected because the vehicle classes were the same as the primary EPA vehicle classes.3/ It contains mileage accumulation data covering a twenty year period for four major vehicle classes:

LLDT - light-duty trucks: ≤6,000 lbs GVWR

HLDT - light-duty trucks: 6,001-8,500 lbs GVWR

HDG - gasoline-fueled heavy-duty vehicles: >8,500 lbs GVWR

HDD - diesel heavy-duty vehicles: >8,500 lbs GVWR

1/"The Development of an Emission and Fuel Economy Computer Model for Heavy-Duty Trucks and Buses," John H. Johnson and Anil B. Jambekar, August 1977, EPA-R803782010.

2/This is also available from the Society of Automotive Engineers - SAE Paper 780630.

3/Mobile Source Emission Factors EPA-400/9-78-055, March 1978.

Table 1

Scrappage Rates*

Years	LDT		HDG		HDD	
	A	C	A	C	A	C
1	.00	.00	.00	.00	.00	.00
2	.03	.03	.05	.05	.09	.09
3	.04	.07	.07	.12	.07	.16
4	.05	.12	.09	.21	.07	.23
5	.05	.17	.10	.31	.06	.29
6	.05	.22	.08	.39	.07	.36
7	.05	.27	.07	.46	.06	.42
8	.05	.32	.06	.52	.05	.47
9	.05	.37	.05	.57	.05	.52
10	.04	.41	.05	.62	.05	.57
11	.04	.45	.05	.67	.04	.61
12	.04	.49	.04	.71	.04	.65
13	.04	.53	.04	.75	.04	.69
14	.04	.57	.05	.80	.03	.72
15	.03	.60	.03	.83	.04	.76
16	.04	.64	.03	.86	.03	.79
17	.04	.68	.03	.89	.02	.81
18	.04	.72	.03	.92	.03	.84
19	.03	.75	.02	.94	.02	.86
20	.04	.79	.02	.96	.03	.89
21	.03	.82	.01	.97	.02	.91
22	.03	.85	.01	.98	.02	.93
23	.03	.88	.01	.99	.02	.95
24	.02	.90	.01	1.0	.02	.97
25	.02	.92	-		.01	.98
26	.02	.94	-		.01	.99
27	.01	.95	-		.01	1.0
28	.01	.96	-		-	
29	.02	.98	-		-	
30	.02	1.0	-		-	

LDT: All trucks less than 10,000 lb GVW: Classes 1 and 2
HDG: Gasoline trucks above 10,000 lb GVW: Classes 3-8
HDD: Diesel trucks above 10,000 lb GVW: Classes 3-8

* A - annual
C - cumulative

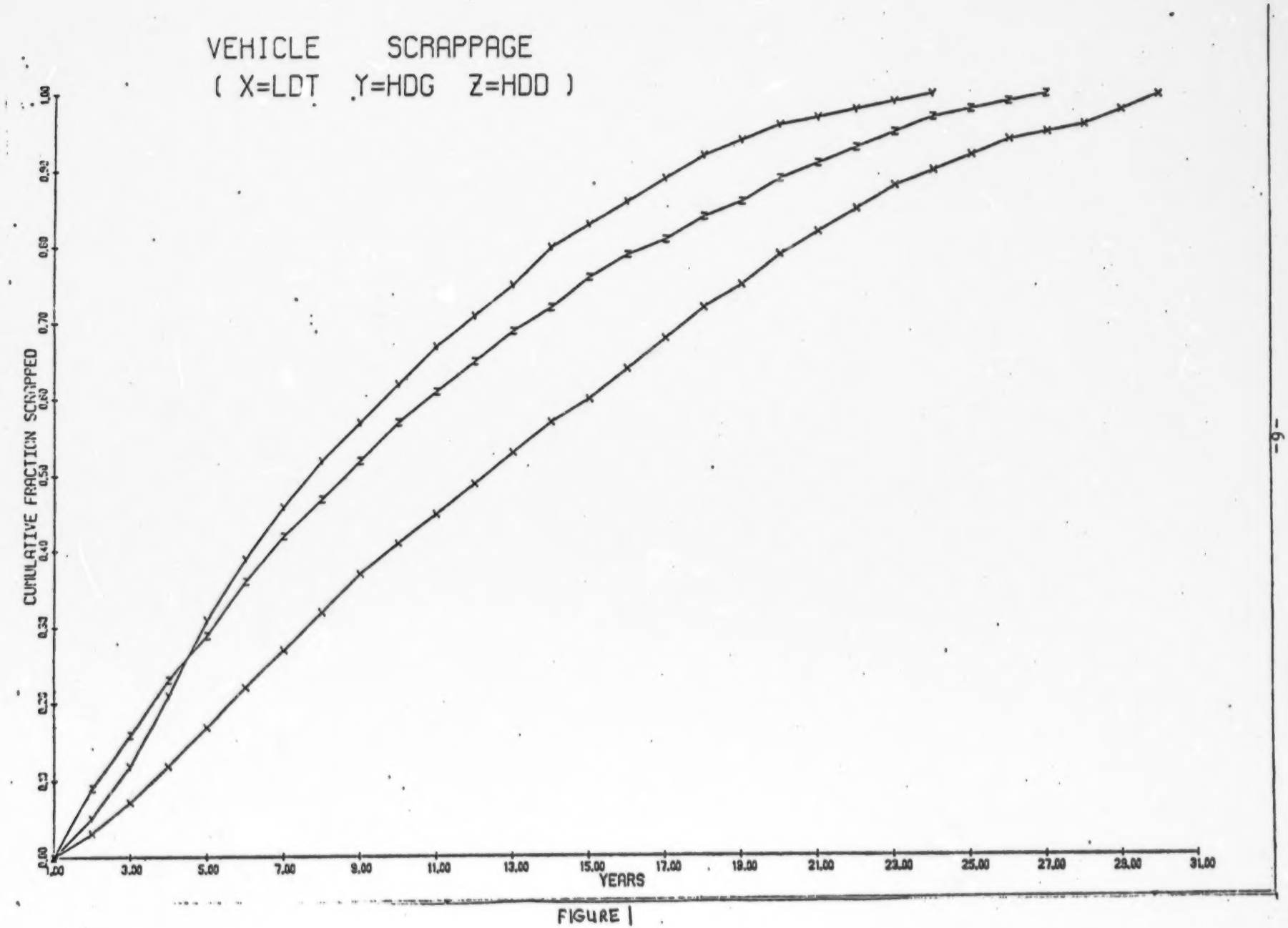
VEHICLE SCRAPPAGE
(X=LDT Y=HDG Z=HDD)
CUMULATIVE FRACTION SCRAPPED
0.00
0.33
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.00
3.00
5.00
7.00
9.00
11.00
13.00
15.00
17.00
19.00
21.00
23.00
25.00
27.00
29.00
31.00
YEARS

FIGURE 1

To make the mileage accumulation rate model given in the emission factors document directly applicable in computing average lifetime periods three adjustments to the data were necessary.

The first adjustment involved extending the mileage accumulation rate data to cover the same number of years as the scrappage rate data. This extension covered 10 years for LLDT and HLDT, 4 years for HDG and 7 years for HDD. This extension was accomplished using the "Fraction Reduction in Vehicle Miles Traveled with Age" data found in the Johnson and Jambekar report, and assuming (1) that LDTs are classes 1 and 2, (2) most HDG vehicles are class 6 and most HDD vehicles are classes 7, 8 and (3) the fraction reduction decreases a small amount each year after eighteen years.

The data actually used in this extension is found in Table 2. The manner in which this data was used is shown in the example below:

HDG Vehicles

Year 21: (.21) 19,000 miles = 3990 or 4000 miles.
Year 22: (.20) 19,000 miles = 3800 miles.

This same methodology was used to compute the mileage accumulation data found in the emission factors document. Tables 3, 4, and 5 contain the mileage accumulation data extended to the same number of years as the scrappage data for LDT, HDG, and HDD.

The mileage accumulation data shown in Tables 3, 4, and 5 represents the number of miles the average vehicle would travel in each year of its life. This data is useful in that it accounts for the wide variety of vehicle usage patterns.

Secondly, in computing the average annual mileage accumulation rate for a fleet of vehicles the rate at which the vehicles in the fleet are placed into service must also be considered. Assuming that vehicles are sold at a constant rate throughout the model year, and each vehicle accumulates its annual mileage (Tables 3, 4, 5) at a constant rate, the desired values of average annual mileage accumulation for the fleet can be computed.

If the assumptions stated in the previous paragraph are used then the average vehicle in a fleet of new vehicles will be six months old at the end of the first year and will have accumulated one half of the annual mileage expected in Tables 3, 4, or 5. At the end of the second year, the average vehicle in the fleet will be one and one-half years old and will have accumulated all of the mileage expected by the average vehicle during its first year plus one-half of the second year's mileage.

Using LLDT as an example:

Year 1: .5(15,900) = 7,950 miles
Year 2: .5(15,900) + .5(15,000) = 15,450 miles
Year 3: .5(15,000) + .5(14,000) = 14,500 miles

Table 2

Fraction Reduction in Vehicle Miles Traveled with Age

Age	LDT	HDG	HDD
21	.24	.21	.17
22	.22	.20	.13
23	.20	.19	.10
24	.18	.18	.07
25	.16	-	.05
26	.14	-	.03
27	.12	-	.01
28	.10	-	-
29	.08	-	-
30	.06	-	-

Table 3

Vehicle Mileage Accumulation Rates - LDT*

Vehicle Year	LLDT <6,000 lbs GVW A	LLDT <6,000 lbs GVW C	HLDT 6-8,500 lbs GVW A	HLDT 6-8,500 lbs GVW C
1	15,900	15,900	15,700	15,700
2	15,000	30,900	15,700	31,400
3	14,000	44,900	14,100	45,500
4	13,100	58,000	12,600	58,100
5	12,200	70,200	11,300	69,400
6	11,300	81,500	10,200	79,600
7	10,300	91,800	9,400	89,000
8	9,400	101,200	8,600	97,600
9	8,500	109,700	8,000	105,600
10	7,600	117,300	7,500	113,100
11	6,700	124,000	7,100	120,200
12	6,600	130,600	6,600	126,800
13	6,200	136,800	6,300	133,100
14	5,900	142,700	6,000	139,100
15	5,500	148,200	5,500	144,600
16	5,100	153,300	5,200	149,800
17	5,000	158,300	5,000	154,800
18	4,700	163,000	4,700	159,500
19	4,400	167,400	4,400	163,900
20	4,000	171,400	4,100	168,000
21	3,700	175,100	3,800	171,800
22	3,400	178,500	3,500	175,300
23	3,100	181,600	3,100	178,400
24	2,800	184,400	2,800	181,200
25	2,400	186,800	2,500	183,700
26	2,100	188,900	2,200	185,900
27	1,800	190,700	1,900	187,800
28	1,500	192,200	1,600	189,400
29	1,200	193,400	1,300	190,700
30	900	194,300	900	191,600

*A - annual
C - cumulative

Table 4

Vehicle Mileage Accumulation Rate - HDG

Vehicle Year	Annual	Cumulative
1	19,000	19,000
2	19,000	38,000
3	17,900	55,900
4	16,500	72,400
5	15,000	87,400
6	13,500	100,900
7	12,000	112,900
8	10,600	123,500
9	9,500	133,000
10	8,600	141,600
11	7,800	149,400
12	7,000	156,400
13	6,300	162,700
14	5,900	168,600
15	5,300	173,900
16	4,900	178,800
17	4,700	183,500
18	4,600	188,100
19	4,400	192,500
20	4,200	196,700
21	4,000	200,700
22	3,800	204,500
23	3,600	208,100
24	3,400	211,500

Table 5

Vehicle Milage Accumulation Rate - HDD

Vehicle Year	Annual	Cumulative
1	73,600	73,600
2	73,600	147,200
3	69,900	217,700
4	63,300	280,400
5	56,600	337,000
6	50,000	387,000
7	45,600	432,600
8	41,200	473,800
9	38,200	512,000
10	36,000	548,000
11	34,600	582,600
12	33,800	616,400
13	33,100	649,500
14	32,400	681,900
15	30,900	712,800
16	28,700	741,500
17	25,700	767,200
18	21,300	788,500
19	18,400	806,900
20	15,400	822,300
21	12,600	834,900
22	9,600	844,500
23	7,400	851,900
24	5,000	856,900
25	3,700	860,600
26	2,200	862,800
27	700	863,500

Thus, it can be seen that the average mileage accumulated by a vehicle in a fleet in any year x will be one-half of the sum of the mileage accumulation for year x and year (x-1). The final fleet average mileage accumulation rates for LLDT, HLDT, HDG, and HDD are shown in Tables 6, 7, and 8 and Figures 2, 3, 4, and 5.

Thirdly, just as the vehicles were introduced at a constant rate in the model year, it can be assumed that the fraction of the total fleet scrapped in any year is scrapped at a constant rate throughout that year. Thus the total accumulated mileage on the average vehicle when it is scrapped in year x is one half of the sum of the cumulative fleet average annual mileage acccummulation in years x and (x-1). This mileage at scrappage data will not be presented for the four vehicle groups considered but will be shown in the sample lifetime calculation which follows.

D. Calculations

As discussed previously, the average lifetime mileage periods can be expressed mathematically as:

$$ALM = \sum_{i=1}^{n} f_i m_i$$

Since the scrappage rates and average annual mileage accumulation rates are now known, the average lifetime in miles, and indirectly in years, can be obtained.

For example, consider heavy-duty gas trucks. As shown in Table 9, using the scrappage and fleet average annual mileage accumulation rates, the average lifetime mileage is computed at about 114,000 miles. To determine the average number of years this represents, go back to Table 7 and find the approximate year by which the average lifetime mileage is reached. In this case it is nine years.

Similar calculations can be made for LDTs and HDD with the following results:

Type Vehicle	Average Lifetime Periods[7]
LLDT ≤ 6,000 lb GVWR	122,000 miles/ 12 years[4]
HLDT 6-8,500 lb GVWR	119,000 miles/12 years[4]
LDT Composite	120,000 miles/12 years[5][6]
HDG	114,000 miles/8 years
HDD	475,000 miles/9 years

4/The same scrappage rates were used for LLDT and HLDT since these were computed for 0-10,000 lb GVWR vehicles.

5/Assumes 55% of the LDTs are 6,000 lbs GVWR or less and 45% are 6,001-8,500 lbs GVWR. These percentages are taken from the Mobile Source Emission Factors document.

6/TERA, Inc. under contract to Oak Ridge National Laboratory recently estimated the average LDT lifetime at 122,300-132,000 miles and 11-12 years and the average passenger car lifetime at 87,300-97,300 miles and 9-10 years. See Vehicle - Miles of Travel Statistics, Lifetime Vehicle Miles of Travel, and Current State Methods of Estimating Miles of Travel, ORNL/TM-6327 Special, David L. Greene and Andrew S. Loebl, February 1979.

7/All results rounded up to the nearest thousand miles.

Table 6

Fleet Average Annual Mileage Accumulation Rates - LDT

Year	LLDT		HLDT	
	Annual	Cumulative	Annual	Cumulative
1	7,950	7,950	7,850	7,850
2	15,450	23,400	15,700	23,550
3	14,500	37,900	14,900	38,450
4	13,550	51,450	13,350	51,800
5	12,650	64,100	11,950	63,750
6	11,700	75,800	10,750	74,500
7	10,800	86,600	9,800	84,300
8	9,850	96,450	9,000	93,300
9	8,950	105,400	8,300	101,600
10	8,050	113,450	7,750	109,350
11	7,150	120,600	7,300	116,650
12	6,650	127,250	6,850	123,500
13	6,400	133,650	6,450	129,950
14	6,050	139,700	6,150	136,100
15	5,700	145,400	5,750	141,850
16	5,300	150,700	5,350	147,200
17	5,050	155,750	5,100	152,300
18	4,850	160,600	4,850	157,150
19	4,550	165,150	4,550	161,700
20	4,200	169,350	4,250	165,950
21	3,850	173,200	3,950	169,900
22	3,550	176,750	3,650	173,550
23	3,250	180,000	3,300	176,850
24	2,950	182,950	2,950	179,800
25	2,600	185,550	2,750	182,550
26	2,250	187,800	2,350	184,900
27	1,950	189,750	2,050	186,950
28	1,650	191,400	1,750	188,700
29	1,350	192,750	1,450	190,150
30	1,050	193,800	1,100	191,250

LLDT AVE MILEAGE ACCUMULATION

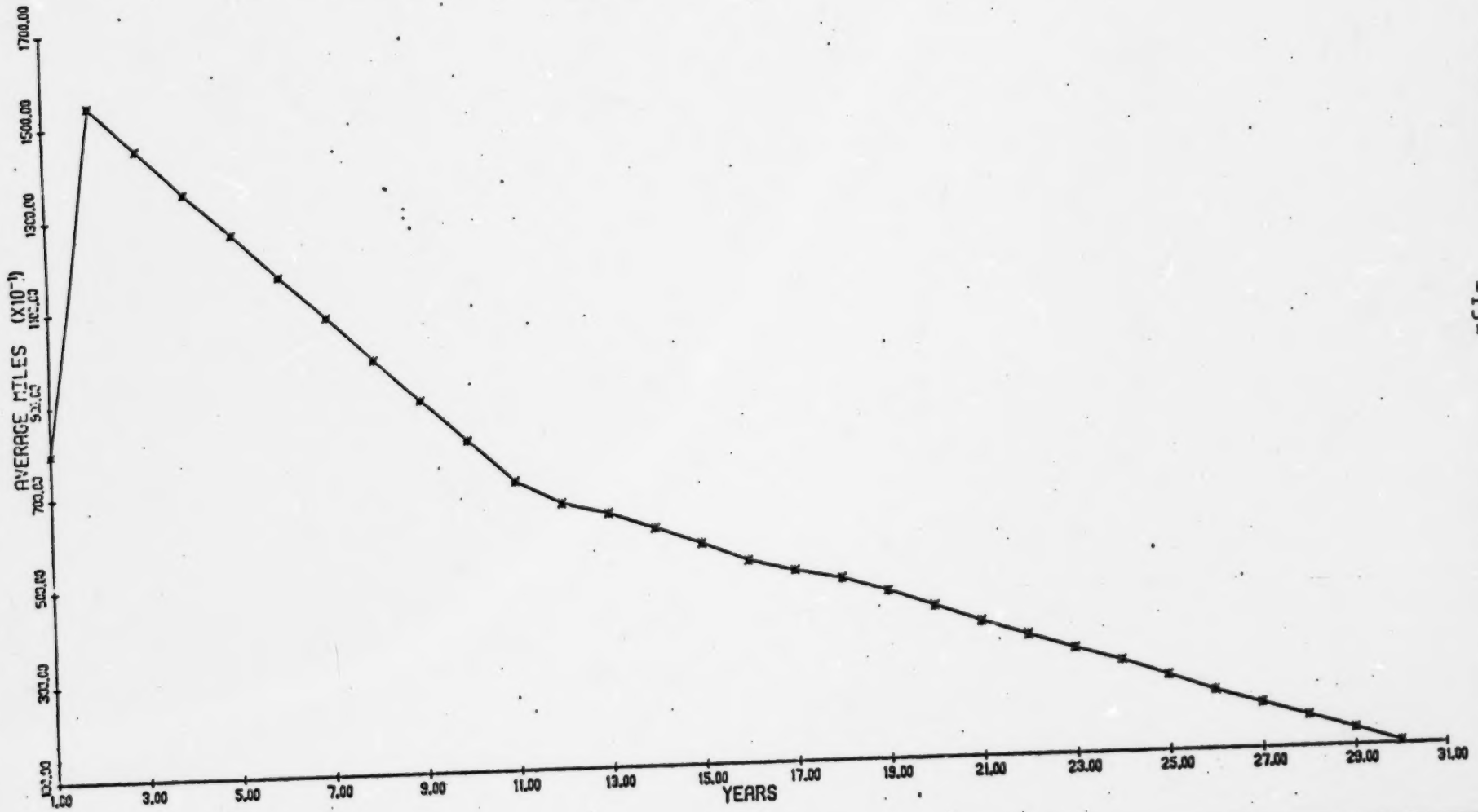

FIGURE 2

HLDT AVE MILEAGE ACCUMULATION

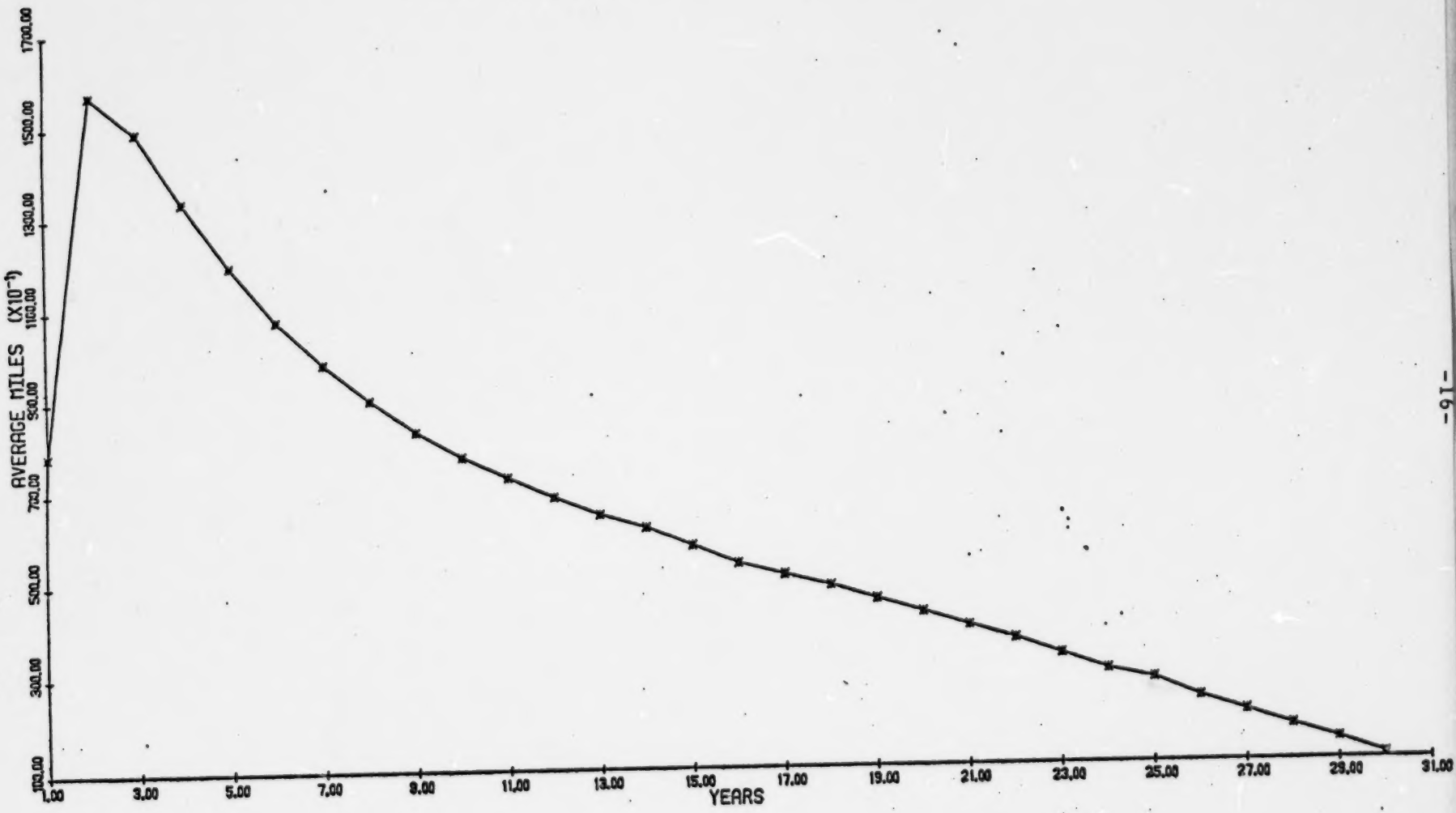

FIGURE 3

Table 7

Fleet Average Annual Mileage Accumulation Rates - HDG

Year	Annual	Cumulative
1	9,500	9,500
2	19,000	28,500
3	18,450	46,950
4	17,200	64,150
5	15,750	79,900
6	14,250	94,150
7	12,750	106,900
8	11,300	118,200
9	10,050	128,250
10	8,950	137,200
11	8,200	145,400
12	7,400	152,800
13	6,650	159,450
14	6,100	165,550
15	5,600	171,150
16	5,100	176,250
17	4,800	181,050
18	4,650	185,700
19	4,500	190,200
20	4,300	194,500
21	4,100	198,600
22	3,900	202,500
23	3,700	206,200
24	3,500	209,700

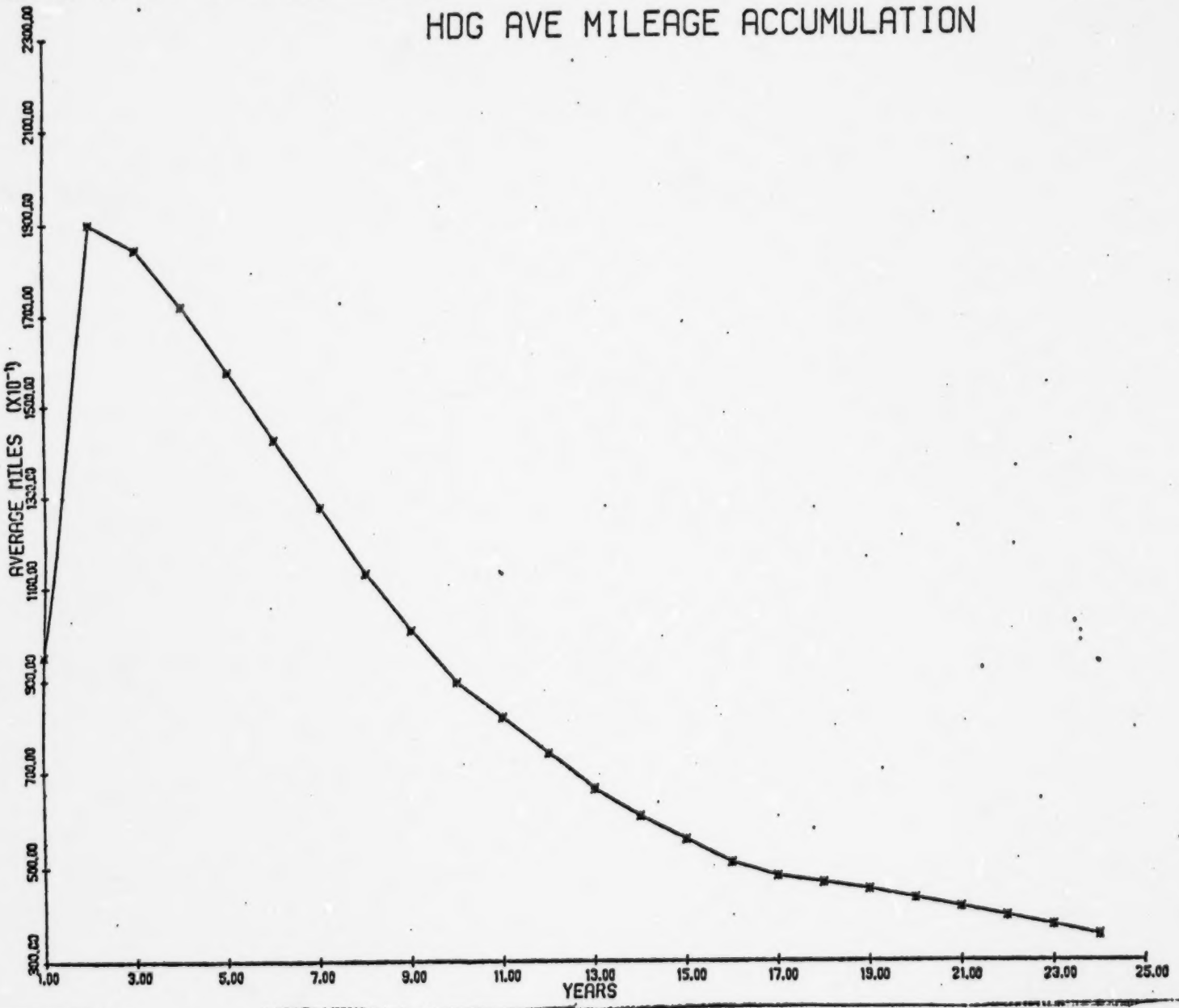
HDG AVE MILEAGE ACCUMULATION
AVERAGE MILES (X10⁻¹)
2300.00
2100.00
1900.00
1700.00
1500.00
1300.00
1100.00
900.00
700.00
500.00
300.00
1.00
3.00
5.00
7.00
9.00
11.00
13.00
15.00
17.00
19.00
21.00
23.00
25.00
YEARS

FIGURE 4

Table 8

Fleet Average Annual Mileage Accmulation Rates - HDD

Year	Annual	Cumulative
1	36,800	36,800
2	73,600	110,400
3	71,750	182,150
4	66,600	248,750
5	59,950	308,700
6	53,300	362,000
7	47,800	409,800
8	43,400	453,200
9	39,700	492,900
10	37,100	530,000
11	35,300	565,300
12	34,200	599,500
13	33,450	632,950
14	32,750	665,700
15	31,150	696,850
16	29,800	726,650
17	27,200	753,850
18	23,500	777,350
19	19,850	797,200
20	16,900	814,100
21	14,000	828,100
22	11,100	839,200
23	8,500	847,700
24	6,200	853,900
25	4,350	858,250
26	2,950	861,200
27	1,450	862,650

HDD AVE MILEAGE ACCUMULATION

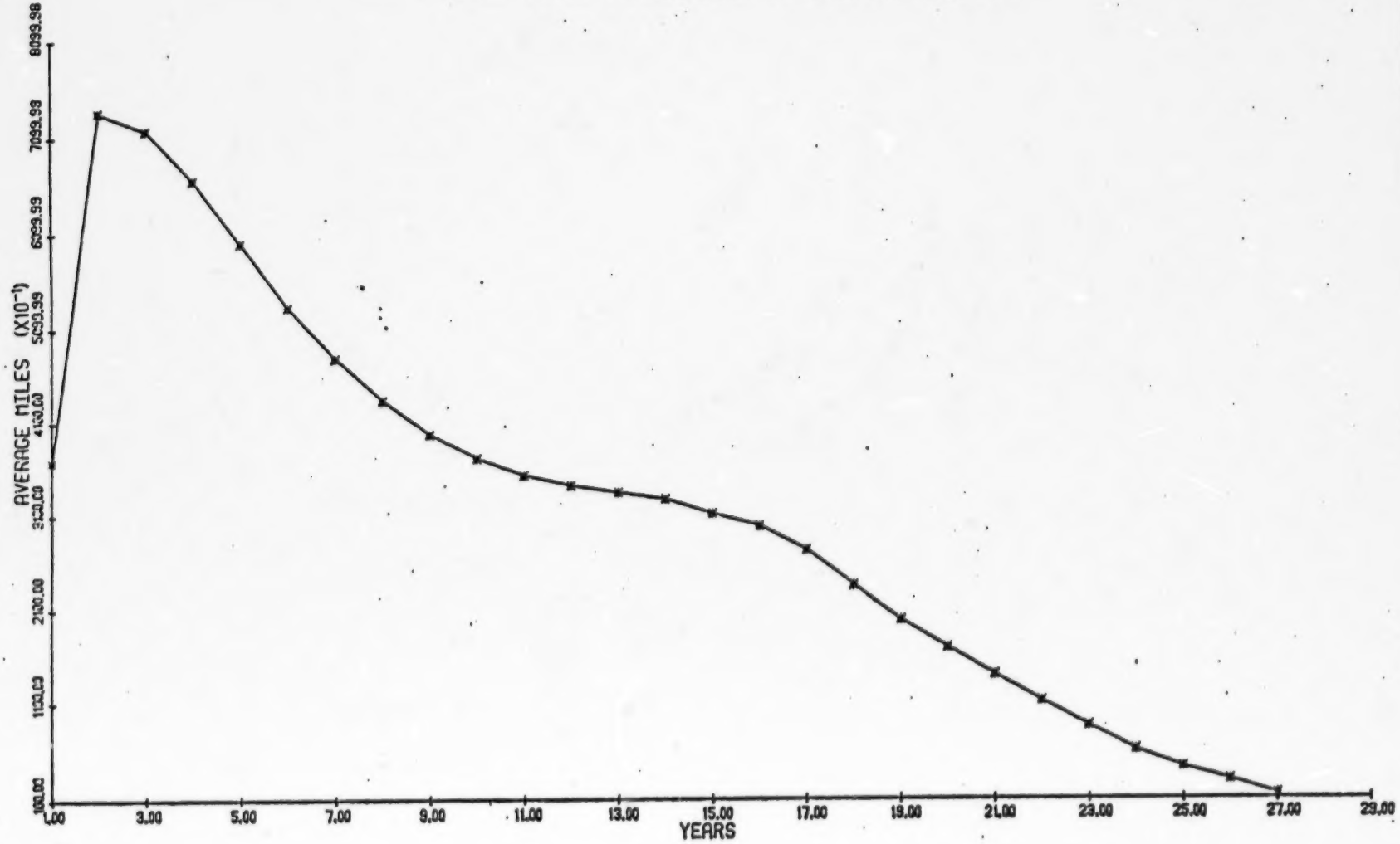

FIGURE 5

Table 9

Sample Average Lifetime Calculation - HDG

Year (i)	Scrappage Rate (fi)	Average[1/] Total Mileage Accumulation	Average[2/] Total Mileage When Scrapped (mi)	$f_i m_i$
1	.00	9,500	4,750	0
2	.05	28,500	19,000	950
3	.07	46,950	37,725	2,641
4	.09	64,150	55,550	5,000
5	.10	79,900	72,025	7,203
6	.08	94,150	87,025	6,962
7	.07	106,900	100,525	7,037
8	.06	118,200	112,550	6,753
9	.05	128,250	123,225	6,161
10	.05	137,200	132,725	6,636
11	.05	145,400	141,300	7,065
12	.04	152,800	149,100	5,964
13	.04	159,450	156,125	6,245
14	.05	165,550	162,500	8,125
15	.03	171,150	168,350	5,051
16	.03	176,250	173,700	5,211
17	.03	181,050	178,650	5,360
18	.03	185,700	183,375	5,501
19	.02	190,200	187,950	3,759
20	.02	194,500	192,350	3,847
21	.01	198,600	196,550	1,966
22	.01	202,500	200,550	2,006
23	.01	206,200	204,350	2,044
24	.01	209,700	207,950	2,080
	1.00			113,567

1/See Table 7

2/Computed for year (i) by taking one-half of the sum of the average mileage accumulation for year i and year (i-1).

E. Discussion and Conclusions

As was stated previously, the lifetime periods calculated in this report represent lifetime mileages and years for the average vehicle. Light-duty trucks and heavy-duty vehicles operate in a wide variety of applications, usage patterns, load variations, environmental conditions, maintenance schedules and other operator-induced variables which may significantly affect the representativeness of these figures. The analysis in this report gives one method by which the average lifetime period can be computed which inherently accounts for the effects of the variables discussed above. It should be possible for each manufacturer to deduce a more definitive lifetime period for its vehicles and/or engines based on the characteristics of each vehicle/engine line and the vehicle/engine application. The average lifetime mileage figures calculated above are useful because they represent the average for a wide variety of operating conditions and are characteristic of the vehicle classes as a whole.

The average lifetime periods in this report are based on vehicle scrappage rates and not engine retirement or rebuild rates. This leads to the question of the relationship, if any, between average lifetime periods and average periods to engine retirement or rebuild. The definition of engine retirement is obvious, i.e. engine scrappage, but the definition of engine rebuild is not as clear. A report prepared by Arthur D. Little, Inc.8/ indicates that vehicle/engine manufacturers consider the average lifetime to be the length of time or distance the engine may be operated before an "in-frame" overhaul is required. Such overhauls include inspection and replacement as required of those parts which can be removed from the engine without removing the engine from the frame of the vehicle. Parts included in this type of overhaul include valves, pistons, piston rings, cylinder liners, and connecting rod bearings.

To provide some means of comparison between average lifetime periods and average periods to overhaul some average period to overhaul data is shown in Table 10.

In comparing these periods no firm conclusions can be drawn. However, some preliminary conclusions are possible:

(1) The average heavy-duty diesel engine undergoes at least one and possibly two overhauls prior to vehicle scrappage.

(2) Heavy-duty gasoline-fueled engines are just as likely scrapped as rebuilt.

8/"Heavy-Duty Vehicle Engine Service Accumulation Cycle," Arthur D. Little, Inc., April 1977, EPA Contract 68-03-2372, this is an unapproved draft report available in public docket #OMSAPC 78-4.

Table 10

Life to Overhaul Data

Engine Type	Service Type	Life to Overhaul (miles)	Type of Overhaul
HDD (>30K GVWR)	linehaul	300,000 - 500,000	out-of-frame 1/
250 HP Turbocharged Diesel - HDD	linehaul	280,000 500,000	in-frame 2/ out-of-frame
HDD	linehaul	300,000	in-frame 3/
HDD	urban	150,000	in-frame 3/
Medium-Duty Diesel	urban	125,000 - 200,000	out-of-frame 1/
Diesel Bus	urban	200,000 - 250,000	in-frame 3/
Light-Duty Gas	variable	100,000	out-of-frame 1/
HDG	variable	100,000	in-frame 3/

1/ Society of Automotive Engineers, SAE Paper 750128.

2/ Society of Automotive Engineers, SAE Paper 700665.

3/ "Heavy-Duty Vehicle Engine Service Accumulation Cycle," Arthur D. Little, Inc., April 1977, EPA Contract 68-03-2372, an unapproved draft report available in public docket #OMSAPC 78-4.

(3) Urban usage leads to much shorter lifetime mileage than over the road usage.

(4) LDTs are more likely retired and replaced in lieu of rebuilding the engine.

The average lifetime periods presented above for light-duty trucks and heavy-duty vehicles have been computed using sound technical methods and engineering judgement. These lifetime mileages and periods are the values which will be used in future rulemaking actions to compute emissions reductions, costs, and cost effectiveness.